*F*usion *E*nergy *S*ciences *P*rogram

Presented to the

Nuclear Task Force
of
PCAST Energy R&D Panel

By

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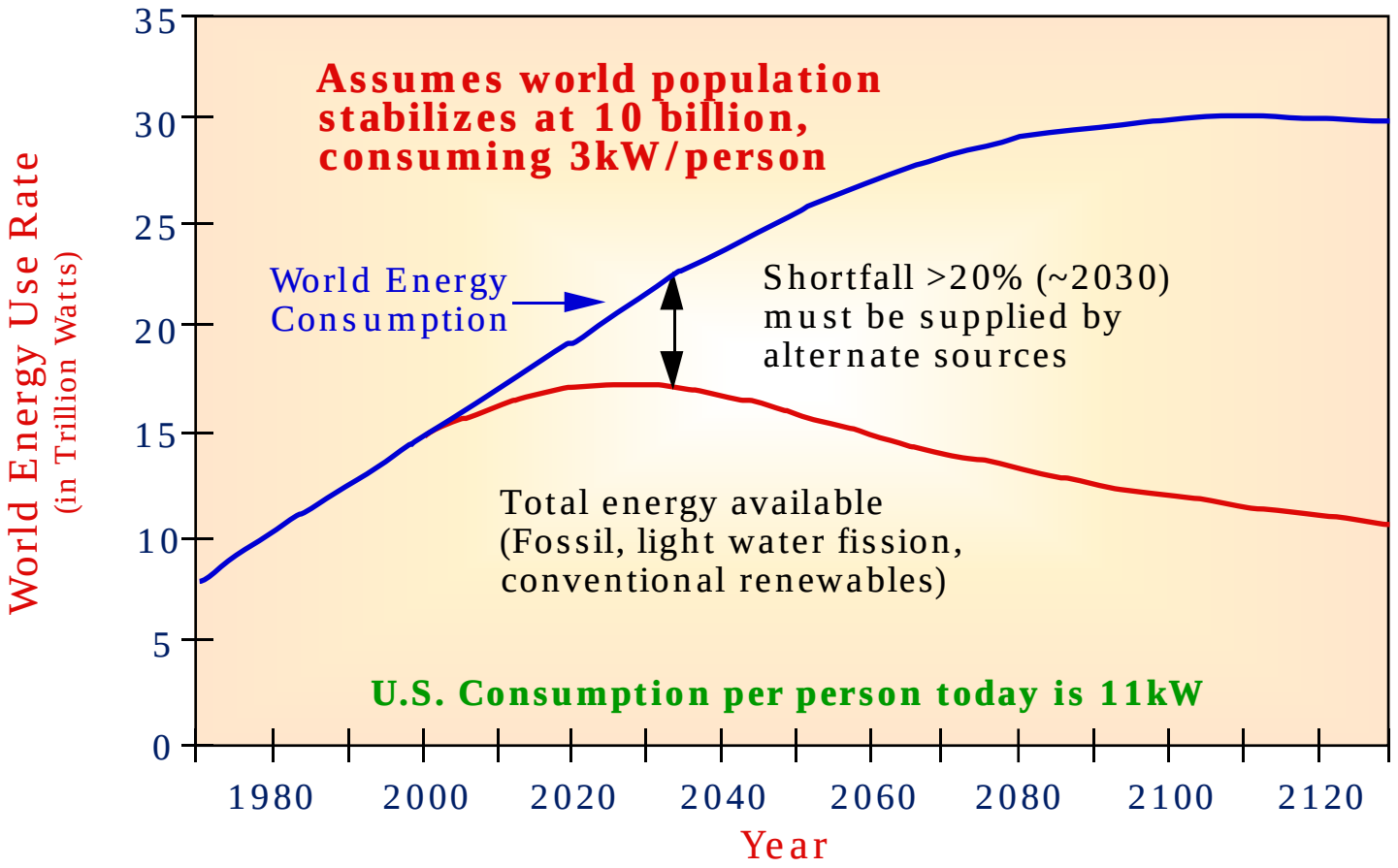
May 20, 1997

The Need for Long Range Energy Solutions

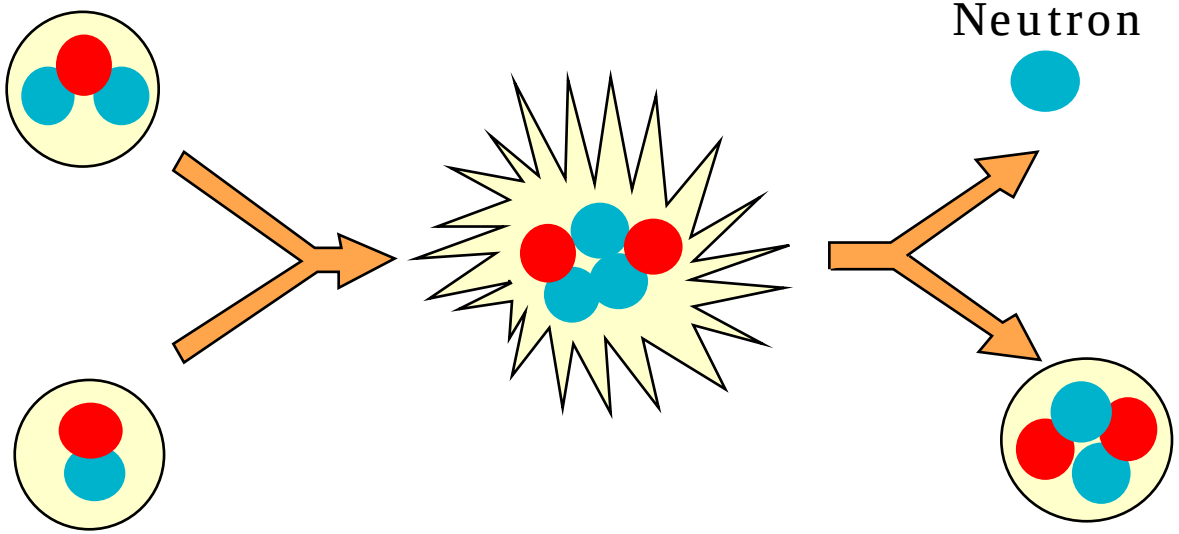


Note: Reconstruction of future world energy demand and supply by G. Logan (LLNL, 1/95) drawn from work of J. Holdren (U.C. Berkeley)

The Fusion Process

Fuel **Reaction** **Products** **Result**

Tritium



Deuterium

"Fast" Neutron

Heat and Tritium Fuel

Helium Nucleus

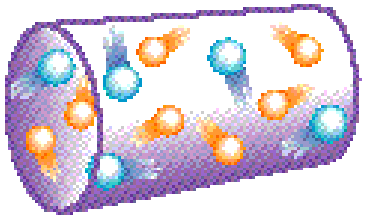
Energy to sustain reaction

Helium gas

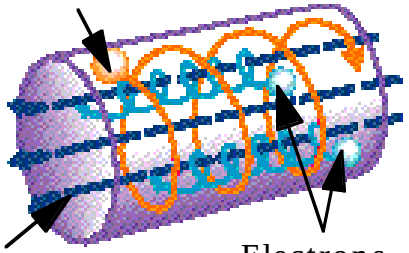
Tritium and Deuterium are "heavy" forms of Hydrogen

Magnetic Confinement of a Plasma

Unconfined

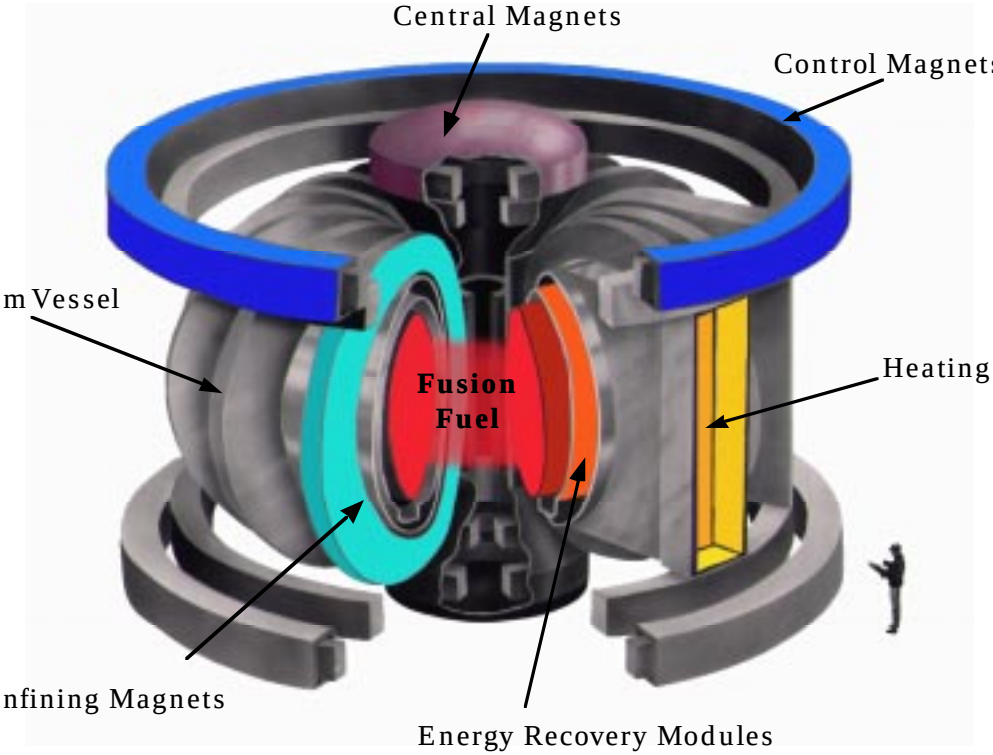


Radially Confined



Toroidal Confinement

(Eliminates end losses in a cylindrical system)

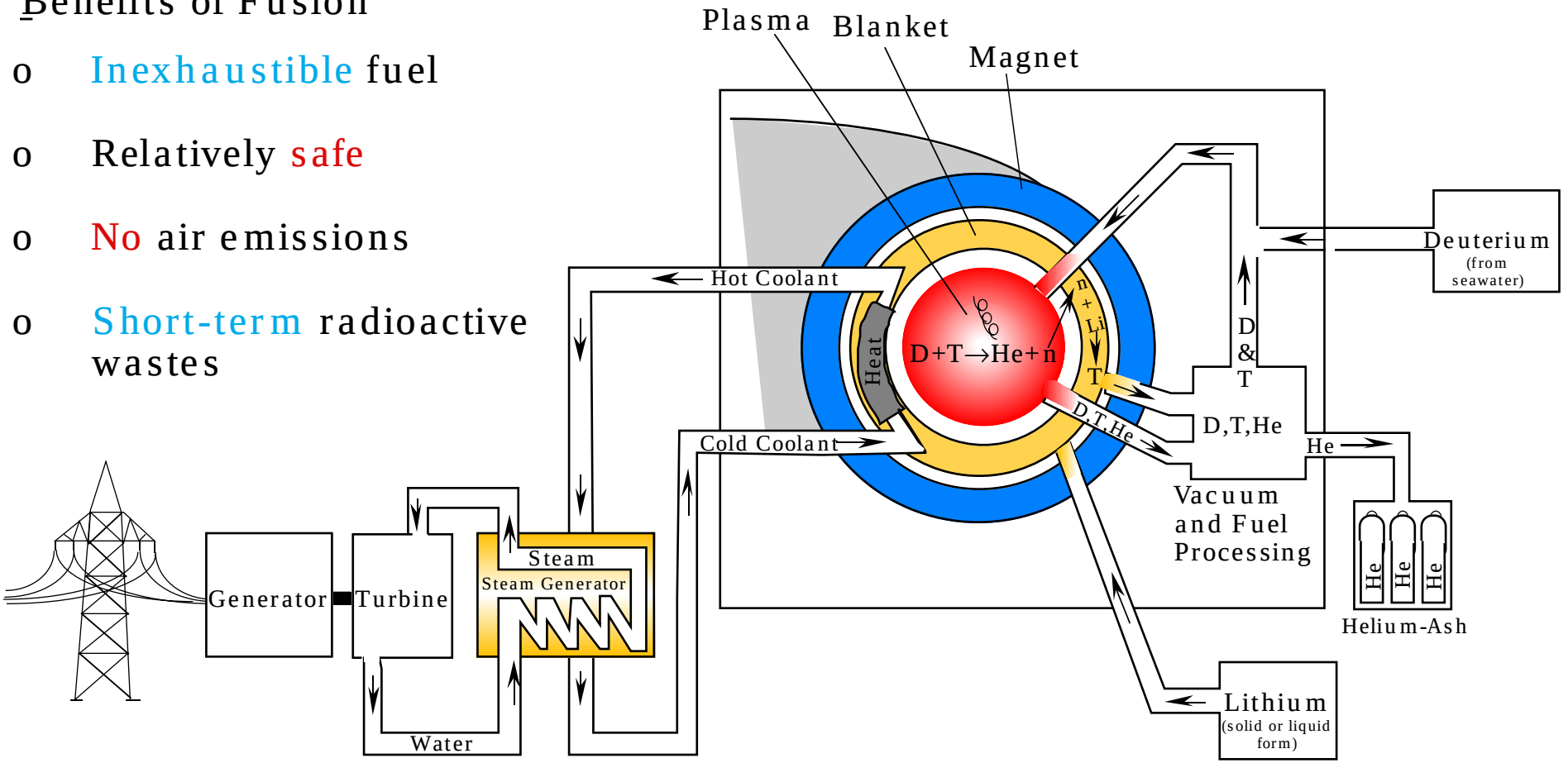


Magnetic Fusion Power Plant

Fueled with Deuterium and Tritium

Benefits of Fusion

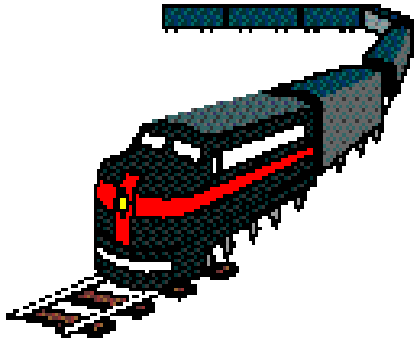
- o Inexhaustible fuel
- o Relatively safe
- o No air emissions
- o Short-term radioactive wastes



Annual Fuel Requirements for a Town of 500,000 People

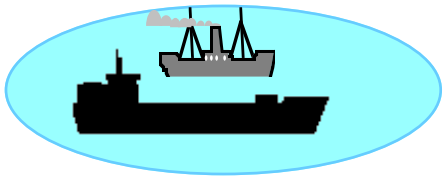
Coal

250 trains



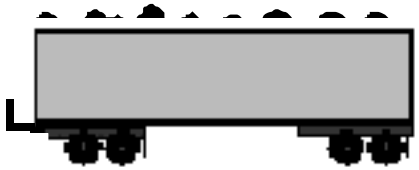
Oil

11 super tankers



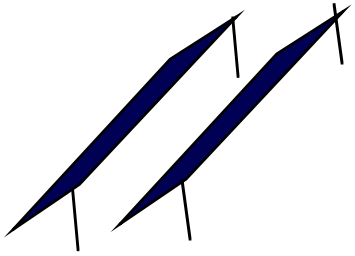
Fission

1.5 rail car load
Uranium Oxide



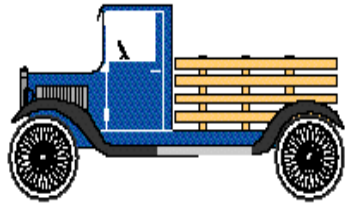
Solar

5000 acres of collectors
plus energy storage for
night and cloudy days



Fusion

1/2 ton pickup truck
Deuterium & Tritium



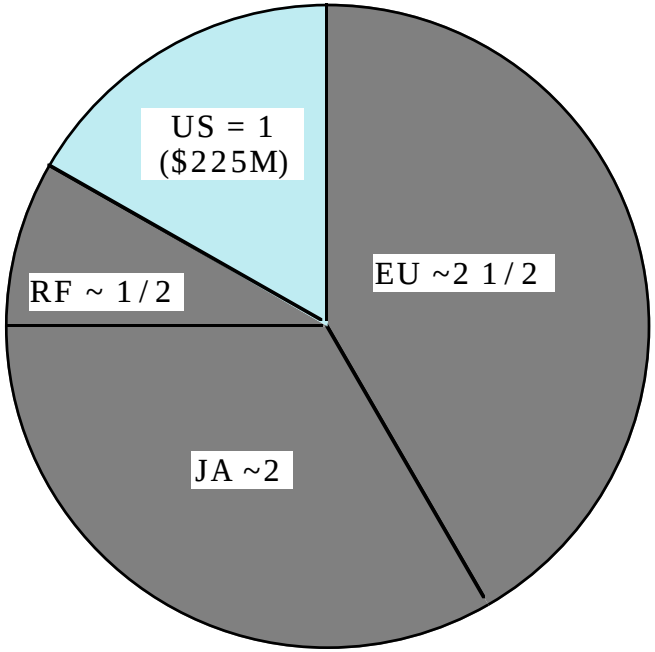
Technical Challenges

- Confining gas hotter than the sun in a vessel with walls at room temperature
- Optimizing the geometry of the magnetic fields
  - Advanced tokamaks
  - Alternates
- Controlling the burn of a self-sustained plasma
- Developing low-activation materials
- Developing components for research and for energy application

Fusion's International Character

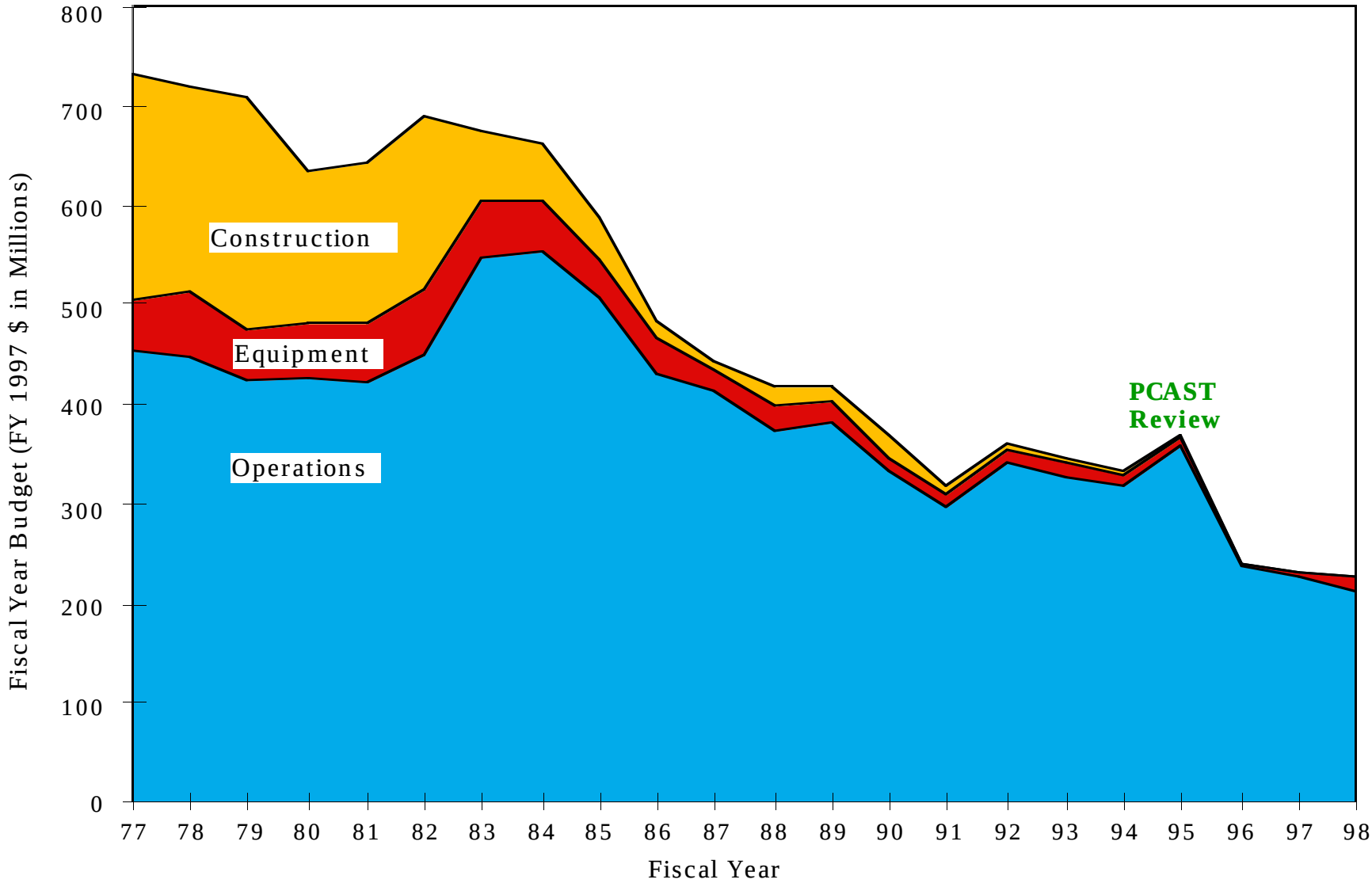
- U.S. has much to gain from international collaboration

Relative fusion program funding



- Existing collaborations involve all aspects of fusion science and technology

U.S. Fusion Budget History



U.S. Fusion Budget History

- Energy no longer perceived to be a problem
- Seeds of recent cuts sown in 1994
  - Senator Johnston's position on ITER
  - EPRI "view"
- Foreseen by PCAST
  - Recommended reduced, but constant funding at $320M
- Renewed emphasis on balancing budget/Science Committee Chariman's view

Recent Fusion Budgets Have Required Restructuring

- FY 1996 budget was 28% less than FY 1995 budget; FY 1997 budget was 4% less than FY 1996 budget

- President's FY 1998 budget request is the same level as FY 1997
  - Loss of about 800 professionals
  - Bare bones operation of scientific facilities
  - Near elimination of component development outside ITER
  - Shutdown of TFTR this year
  - Reduction of participation in ITER

- Community participation essential (FEAC, SCICOM, FESAC, Leesburg)

10 Implementing Principles

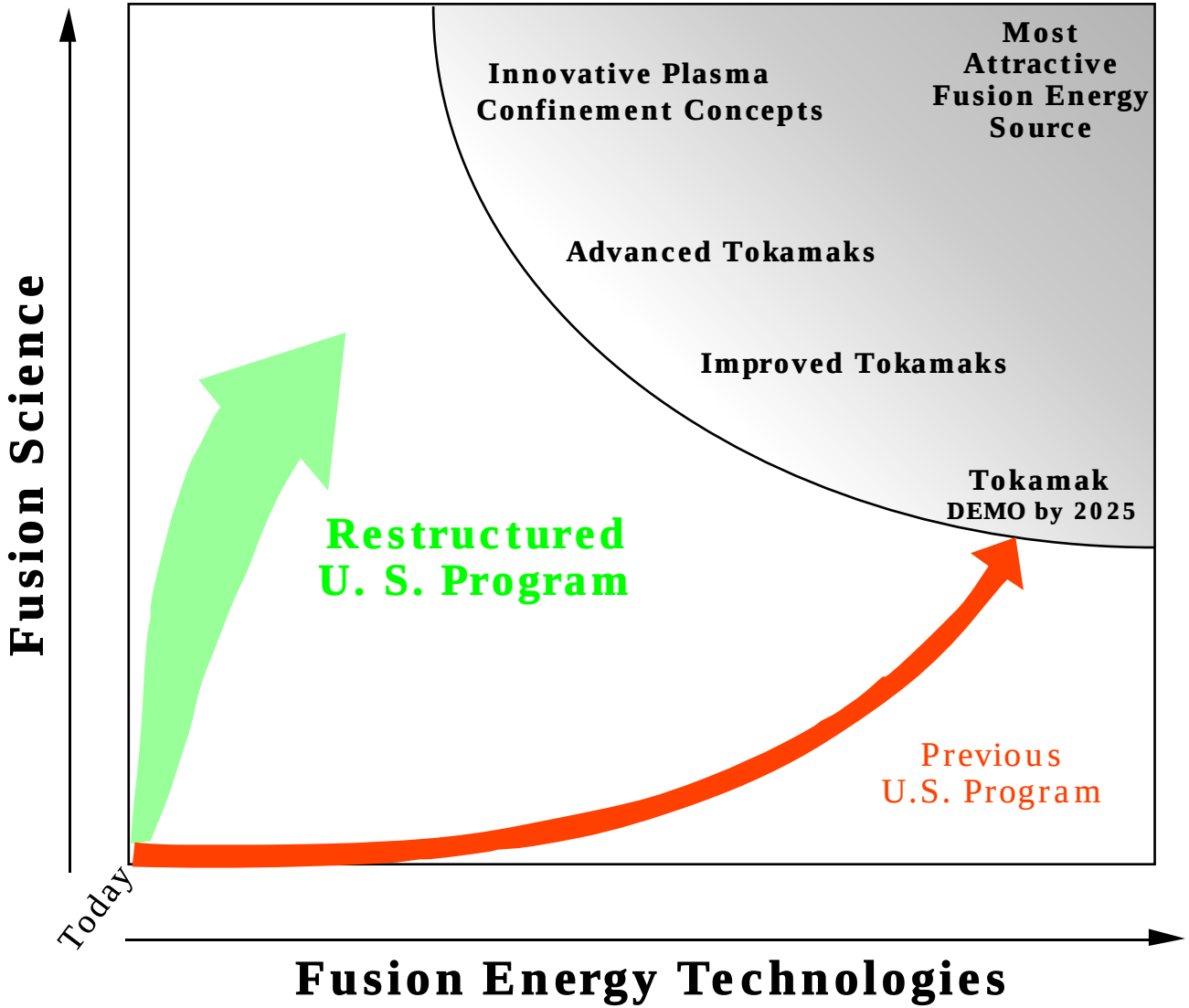
- Science focus
- Energy goal
- Reliability as an international partner
- Complementary to the international effort
- Leadership in selected areas
- Scientific excellence
- Facility balance
- Importance of a national laboratory for fusion science
- Education and human resources
- Diversity of participation

Attributes of Restructured Program

- Elimination of milestones for development of fusion as an energy technology
- Planning and budgeting based on research topics rather than facilities
- Increased focus on innovation
- Smaller, national user facilities
- University/laboratory partnerships
- Increased use of peer review
- Expanded international collaboration
- Increased community involvement in program decisions through FESAC, peer review, and work shops
- Increased outreach activities

U.S. Fusion Energy Sciences Program

Comparison of Strategies for Restructured and Previous Programs



A New Mission

Advance plasma science, fusion science, and fusion technology — the knowledge base for an economically and environmentally attractive energy source for the nation and the world

Goals for the Program

I. Understanding the physics of plasma the fourth state of matter

II. Identifying and exploring innovative and cost-effective development paths to fusion energy

III. Exploring the science and technology of burning plasmas, the next frontier in fusion research, as a partner in an international effort

Five Year Objectives

- Substantial progress in scientific understanding and optimization of toroidal plasmas, with tokamaks the most mature of several related configurations (I, II)

- Strengthened general plasma science and education efforts, with connections to other scientific communities (I)

- Significant improvement in integrated modeling, based on theoretical understanding and the experimental experience base and exploiting anticipated advances in large-scale computation (I)

- Active explorations evaluating several non-tokamak fusion approaches, including the scientific and technological bases for an IFE heavy-ion driver (II)

- Marked progress in the scientific understanding necessary for evaluating technologies and materials required under conditions of high plasma heat flux and neutron wall load (II)

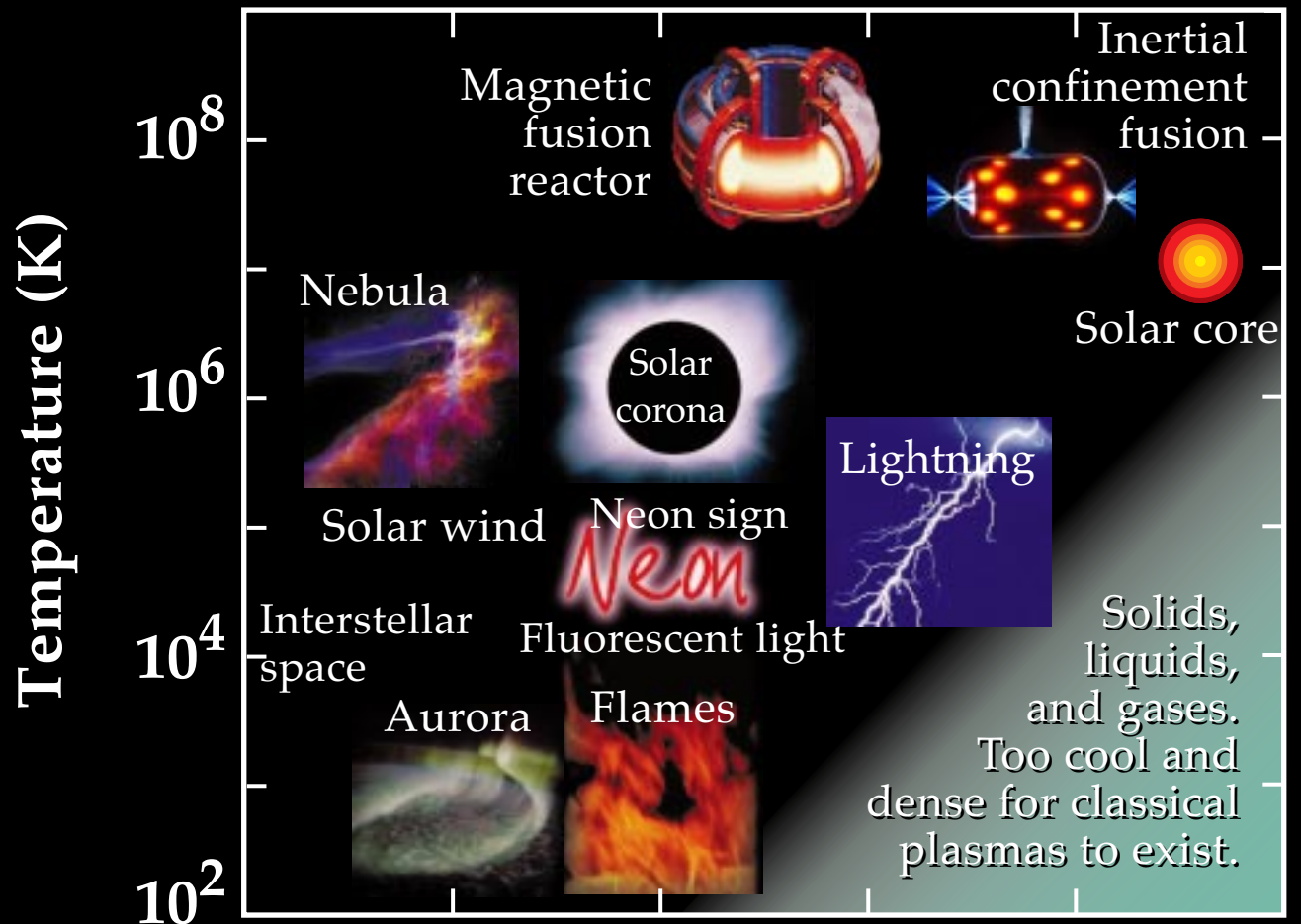
- Membership in an international collaboration to study burning plasma physics and develop related fusion technologies (III)

Goal I
Understanding Plasmas

- Fusion plasma science

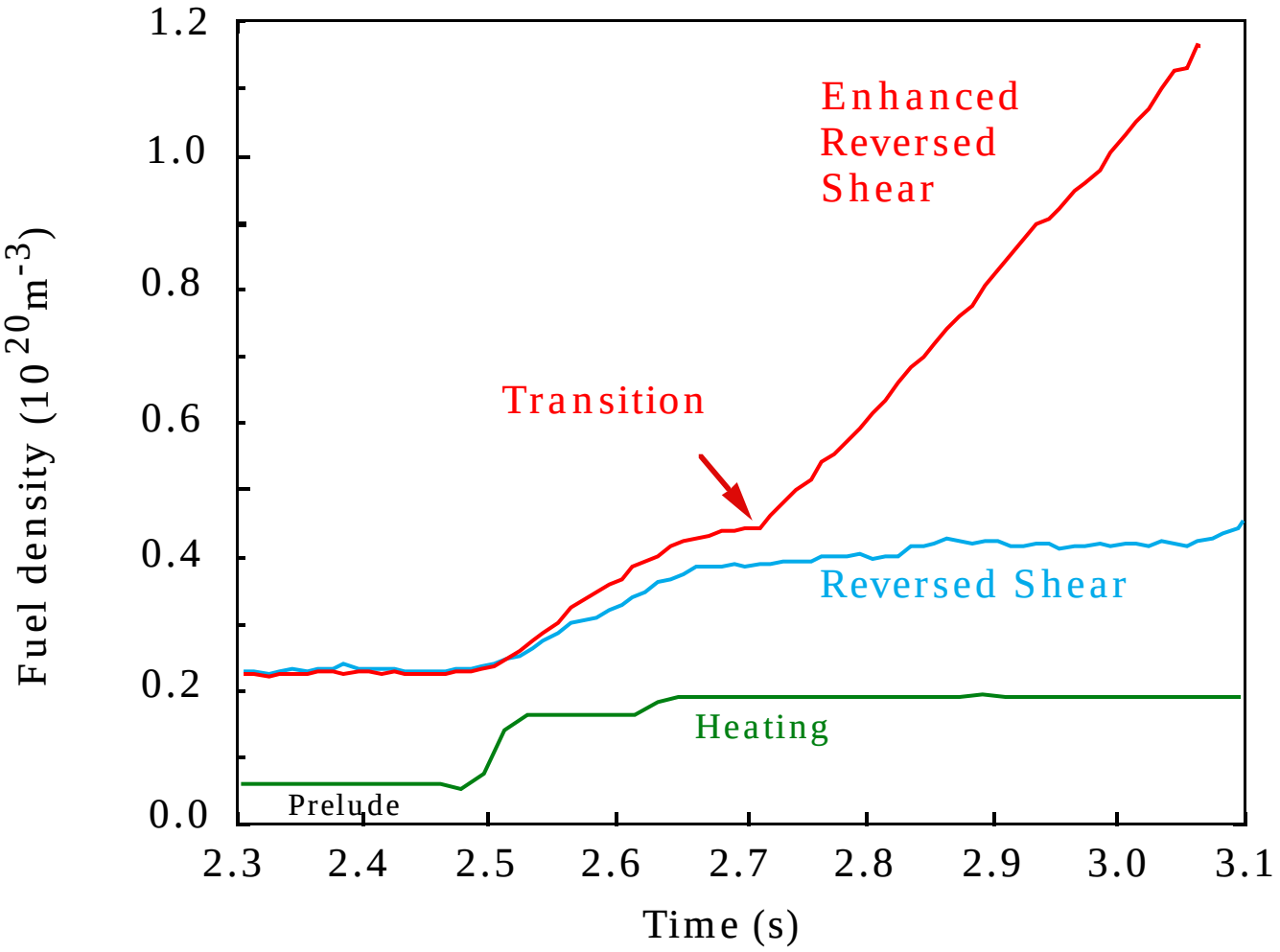
- General plasma science

Plasmas - The 4th State of Matter

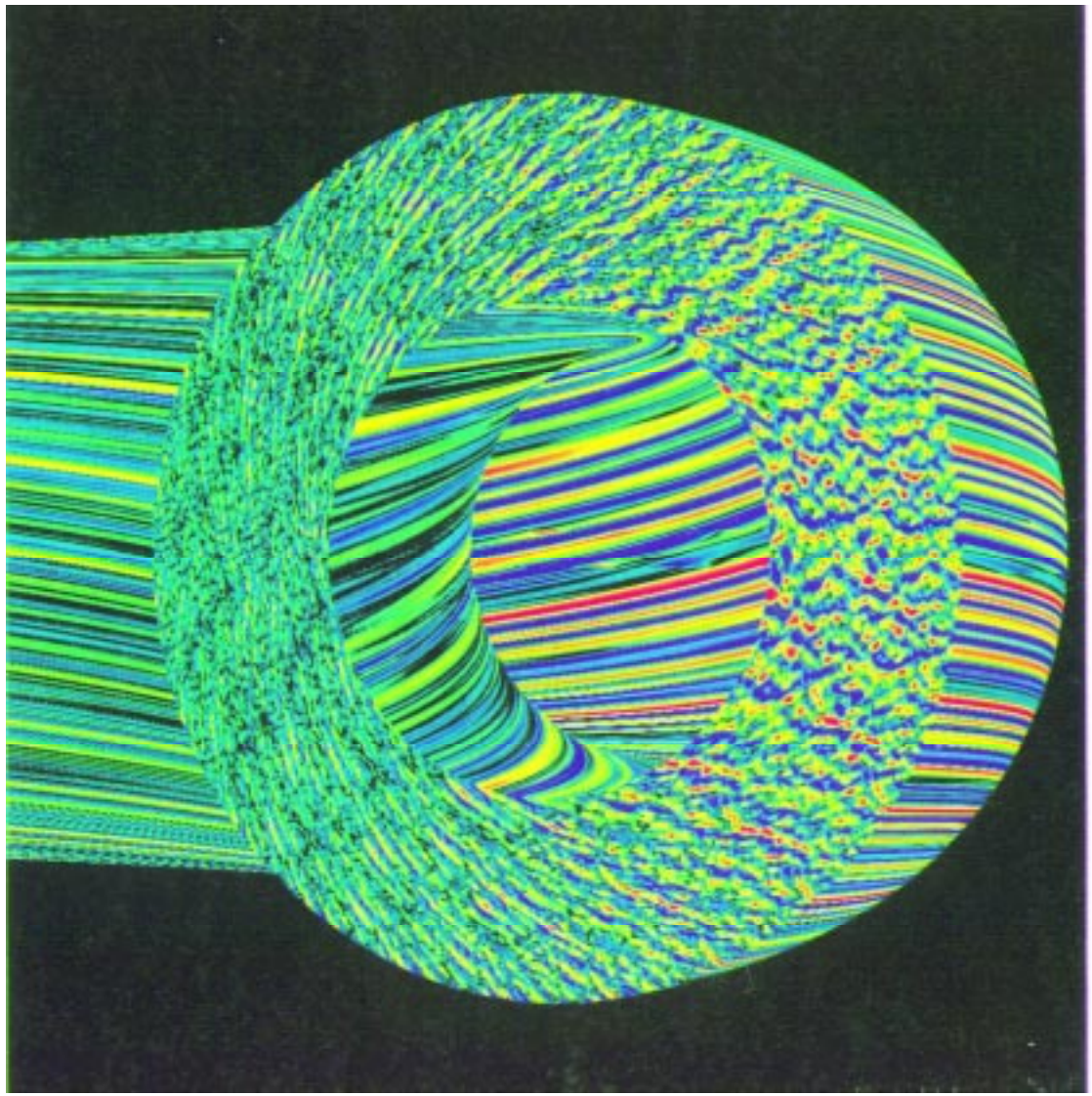


Goal I, II
Progress in Tokamak Plasma Physics

For the first time, theoreticians have predicted and experiments have confirmed our ability to eliminate the turbulence that limits energy confinement in the core of a tokamak



Goal I, II
Calculated Plasma Turbulence



- Shown for an annular section of a tokamak
- This is the simulated turbulence in electric field
    - Similar to the recent measurements
- Particle and energy are readily transported across magnetic field lines within the small cells
- Transport is faster on the outside of the tokamak where cells are larger

Goal I
General Plasma Science Initiatives

- Joint NSF/DOE solicitation for plasma science/engineering proposals: $2M (FY97) from each Agency ($4M total) more than 240 proposals presently in review; decisions by June 15

- DOE principal young investigators grant program: $1M

  - Proposals have been reviewed and decisions have been made

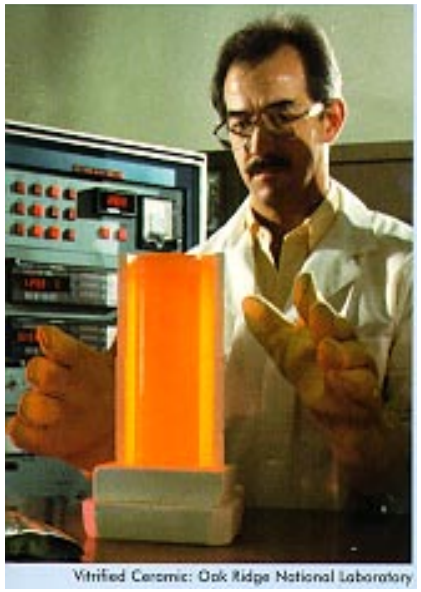
  - Successful applicants will be notified by late May

Goal I
Plasma Science has Broad Impacts on Society

- Plasma Processing of Chips and Circuits

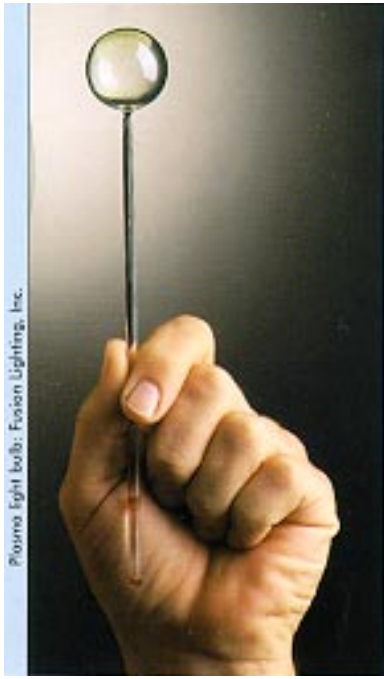
Small, fast computer chips (such as the Pentium chip) have revolutionized the PC industry. About 40% of the steps required to produce such chips and circuits use plasma processing.

Waste Processing



New, efficient technologies for destroying or vitrifying toxic and radioactive waste, using plasmas, are entering the marketplace.

New Technologies



The visible light from a golf-ball-sized plasma, yeilds as much light as 250 one-hundred watt bulbs with a fraction of the energy

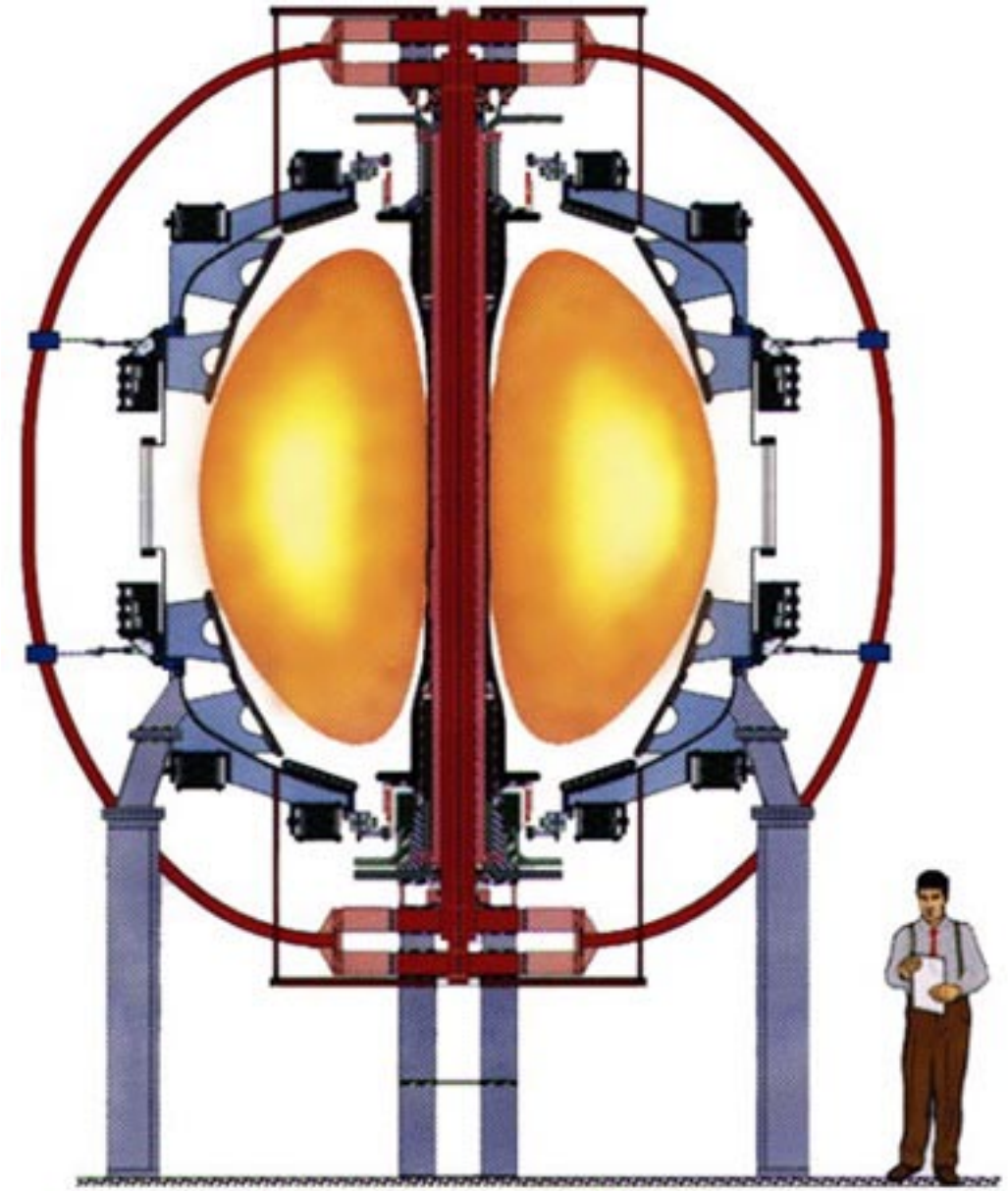
Goal II
Innovations

- Advanced tokamaks
- Alternate magnetic concepts
- Inertial fusion energy

Goal II
Innovative Concept Initiative

- Solicitation for "Innovations in Fusion Energy Confinement Systems" $3M (FY 1998)
  - 42 proposals for FY 1998 funding received
  - Funding decisions July 1997

Goal II
National Spherical Torus Experiment



Features:

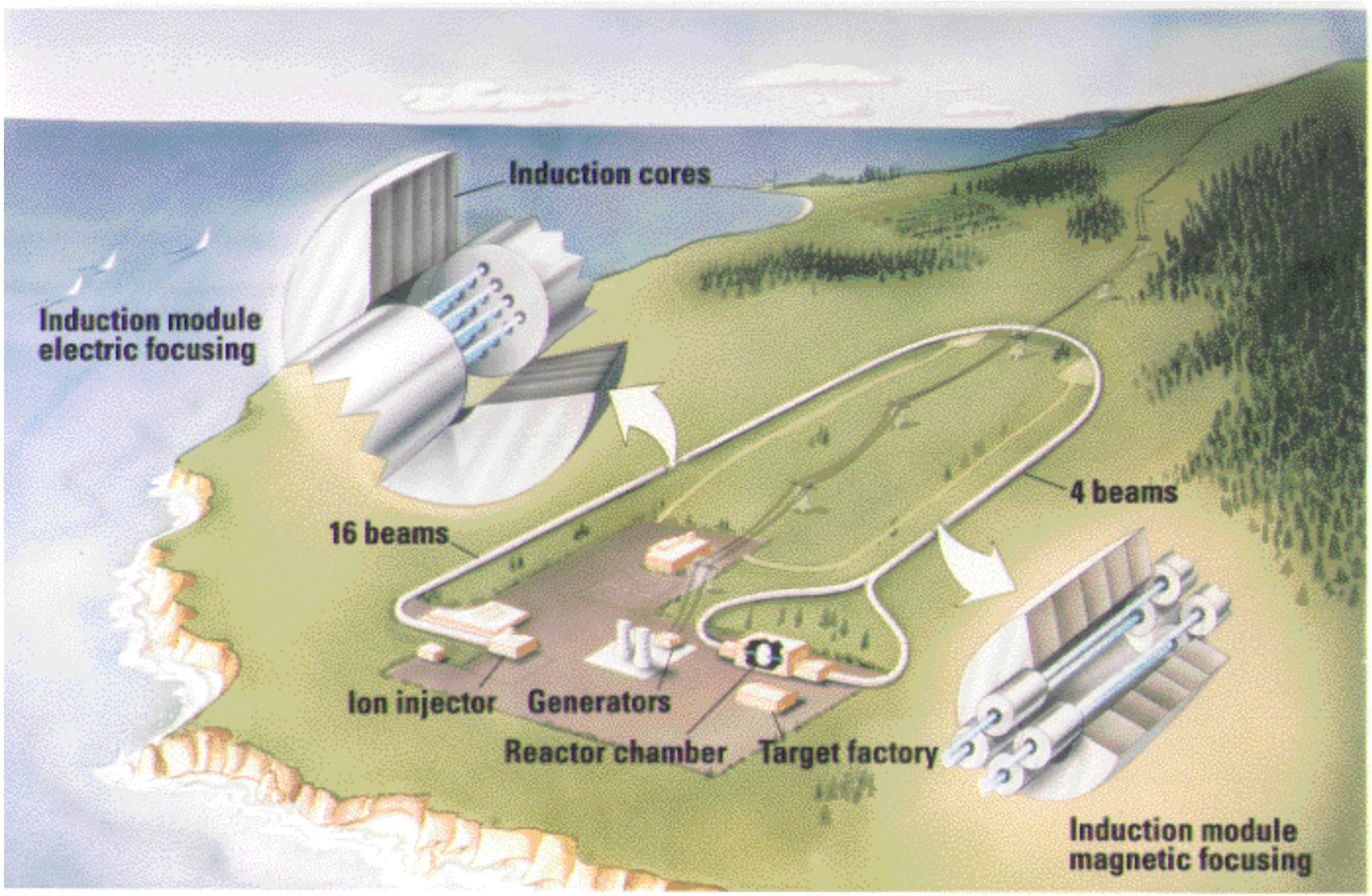
- A physics experiment
- Highly efficient containment of plasma energy, ~30-45%
- Self generates up to 90% of confinement current
- Sustains confinement current up to steady-state
- Extremely compact
- Fusion-like plasma at high temperatures

Goal II
Inertial Fusion Energy

- DP program conducting target physics using NOVA; National Ignition Facility in construction

- ER developing components for energy applications, especially accelerator-based driver

Goal II
An Inertial Fusion Power Plant
Based on a Heavy-Ion Induction Linear Accelerator

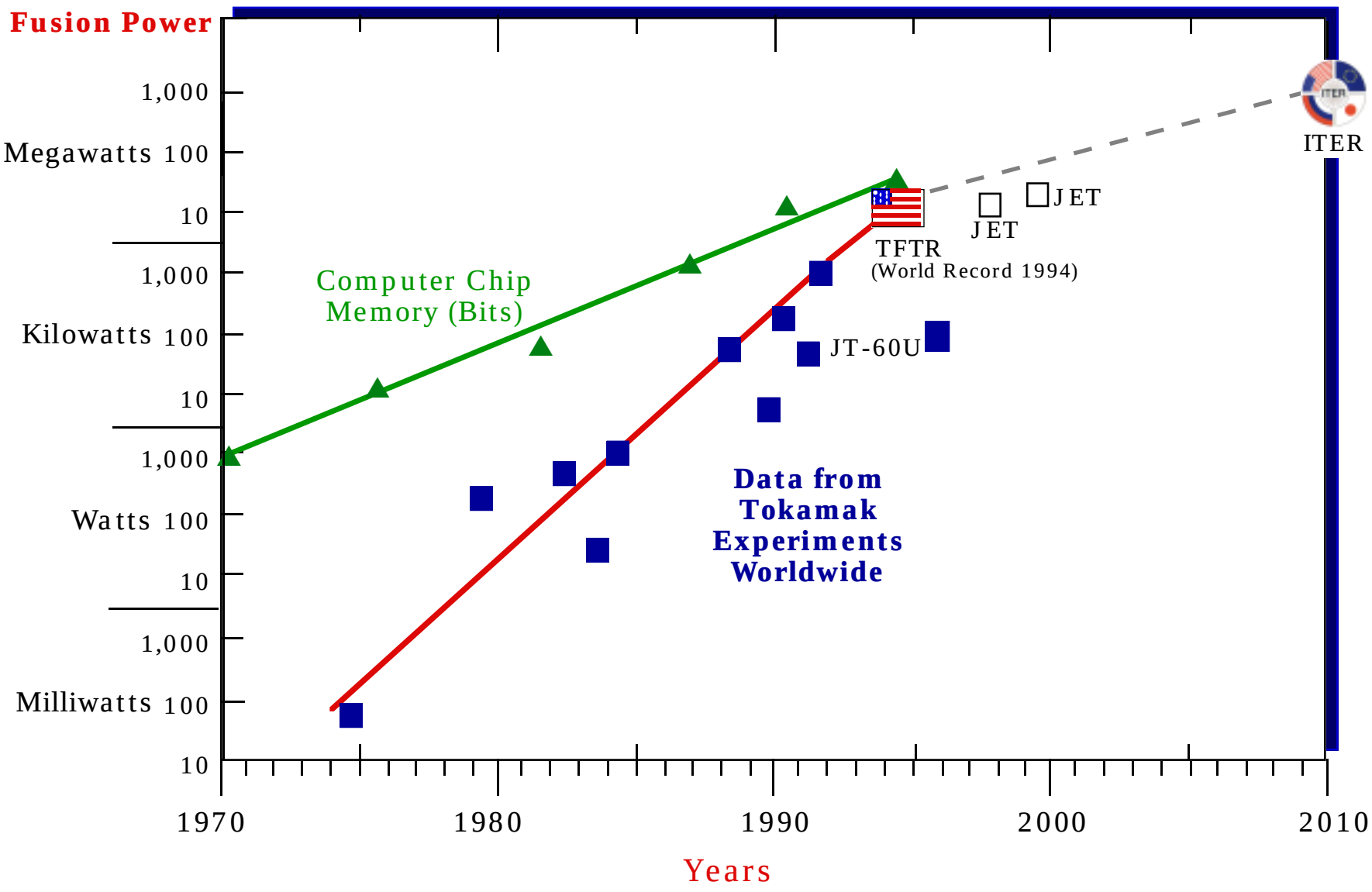


Goal III
Burning Plasma Science

- Near term: TFTR data analysis, JET

- Longer term: ITER

Goal III
Progress in Magnetic Fusion Research



Goal III
International Thermonuclear Experimental Reactor

- ITER is a joint undertaking of the European Union, Japan, Russia, and U.S. as equal partners

- Ultimate objective of ITER facility is to demonstrate scientific and technological feasibility of fusion

- Status

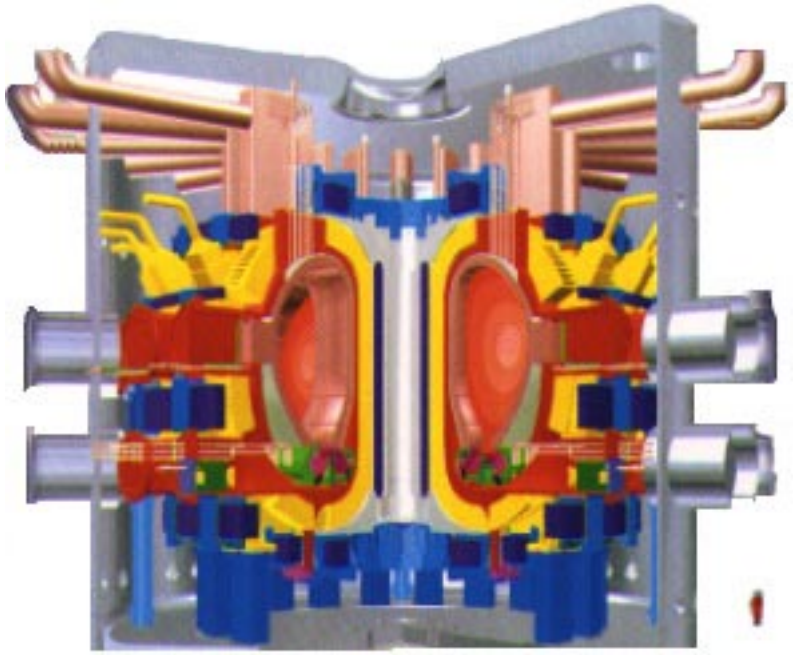
  - Engineering design/R&D phase to be completed in July 1998

  - U.S. now spending $52 million per year (down from planned $82M/year)

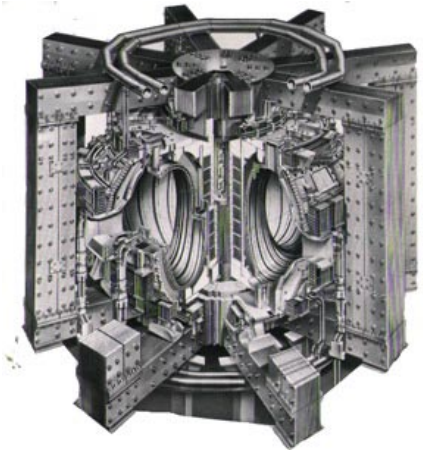
  - Detailed Design Report completed; FESAC review completed

  - Model for large-scale international scientific collaboration

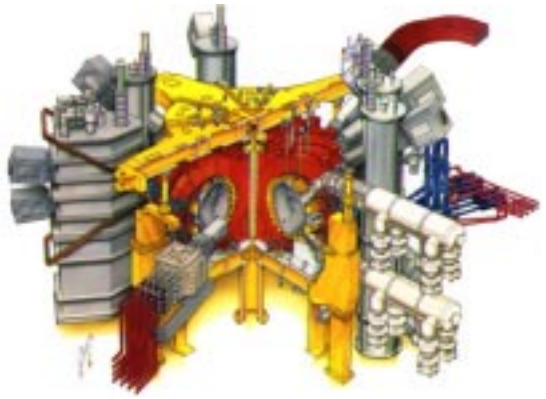
Goal III
Comparison of World Tokamaks



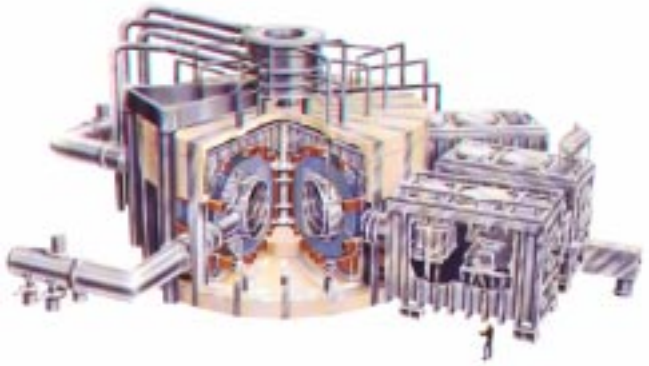
International Thermonuclear Experimental Reactor



Joint European Torus

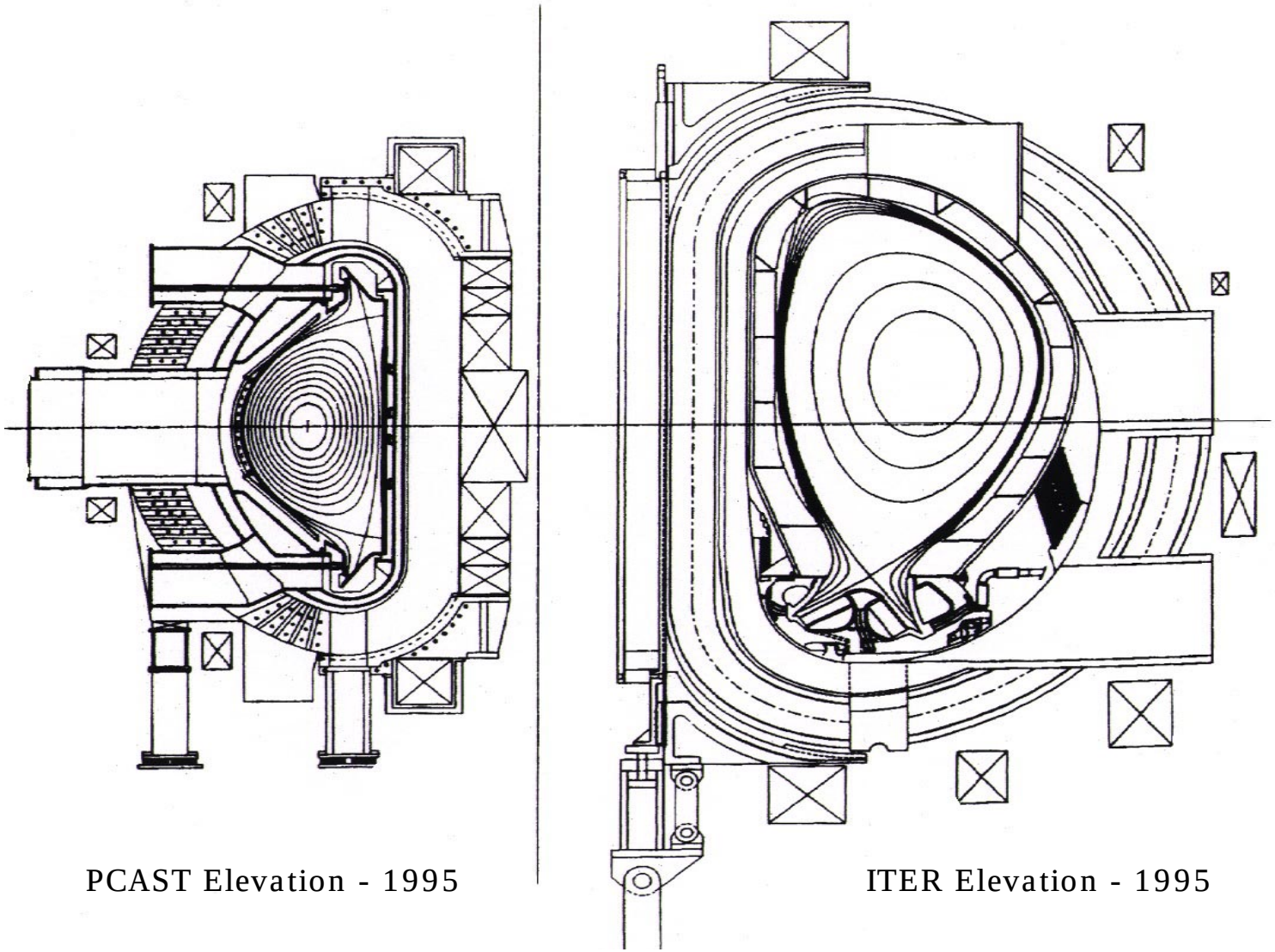


JT-60



Tokamak Fusion Test Reactor

Goal III
PCAST Recommended a Descoped ITER

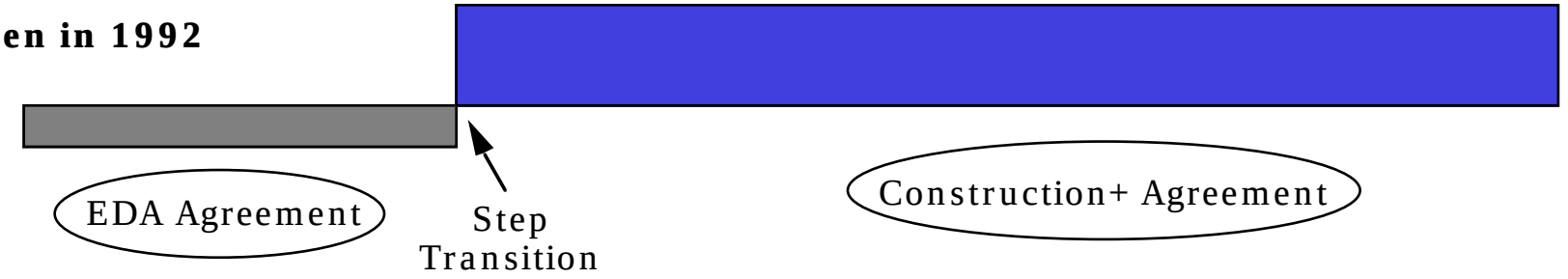


PCAST Elevation - 1995

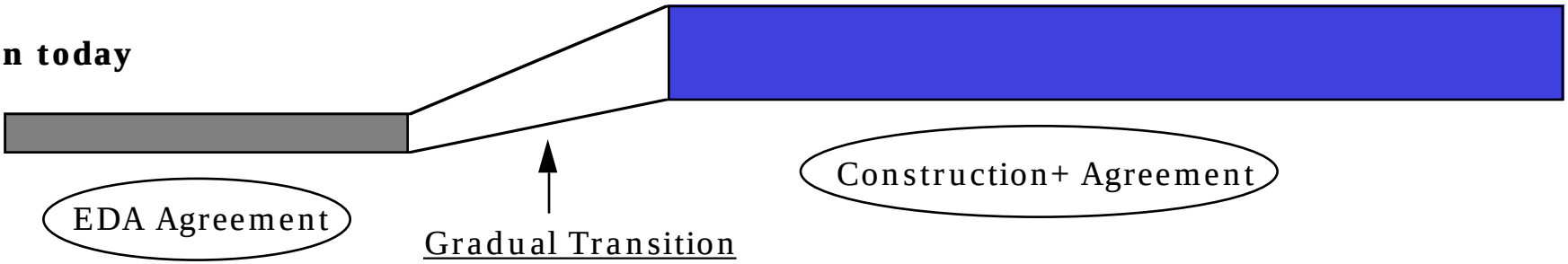
ITER Elevation - 1995

Goal III
The Transition from Engineering to Construction for ITER

As seen in 1992



As seen today



Gradual Transition

- Site-specific design
- Interaction with regulators before license application
- Completion of prototype testing, R&D and design
- Consolidate the scientific basis for ITER operation
- Joint assessment at 2 year point

Near-Term Challenges Facing the Fusion Energy Sciences Program

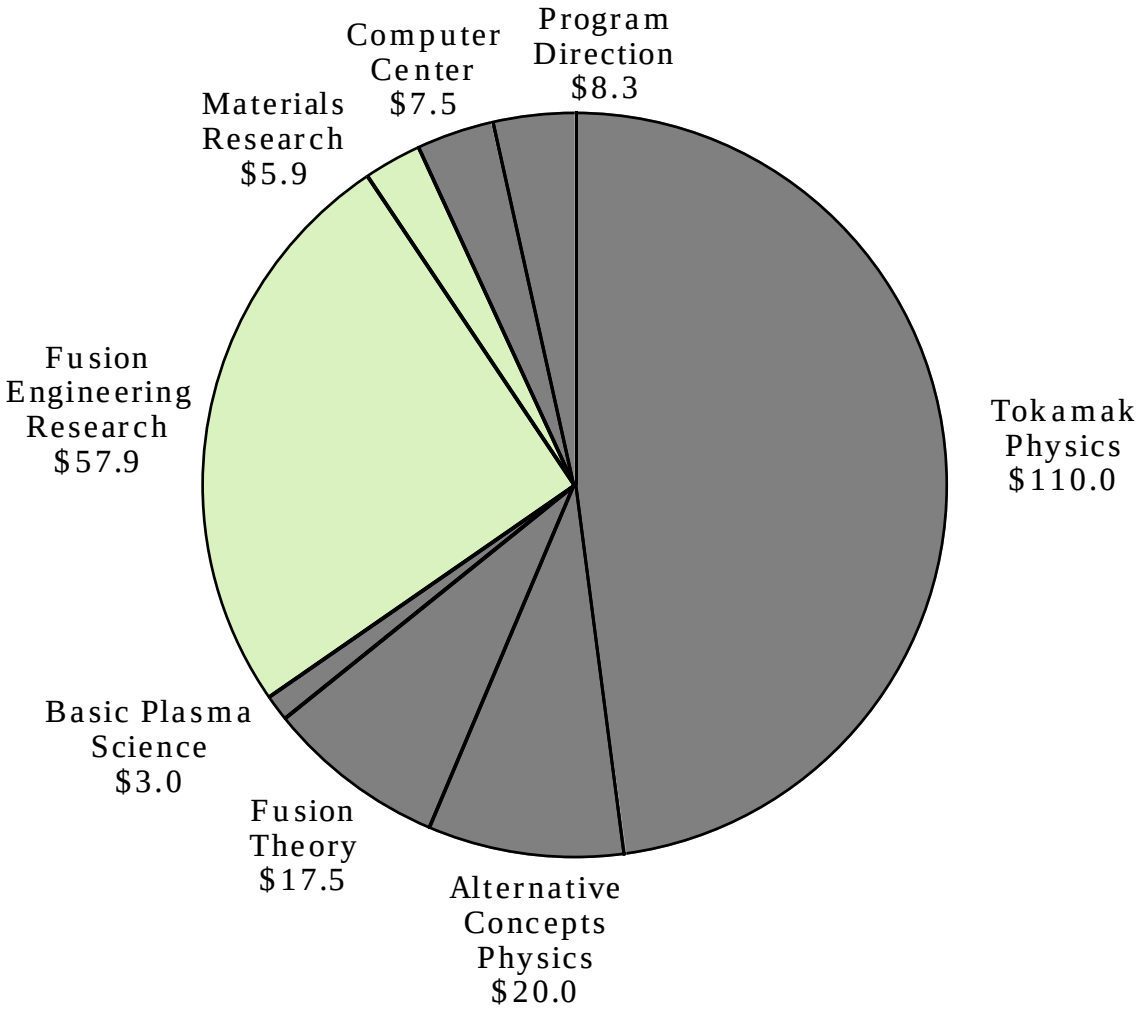
- Restructuring the program with declining budgets
- Role of U.S. in an international burning-plasma experiment
- Transition of PPPL in restructured program

Restructuring More Slowly

- Increase support for basic plasma science research
- Increase support for alternative concepts research
- Increase level of experimentation on two remaining tokamaks
- Increase participation in major experiments abroad
- Meet commitment to ITER EDA
- Participate in next phase of ITER while preparing for a decision on construction and maintaining domestic science program

FY 1997 Office of Fusion Energy Sciences Budget

$ in Millions



$230.1M

Science Committee Action

April 16, 1997

"The Committee provides an additional $15 million for the Fusion Energy Sciences program with the intent that these dollars be used for initiating and strengthening work in alternate confinement concepts; increasing utilization of the remaining two major experiments; strengthening and maintaining diversity in the theory and computational programs; and strengthening basic fusion sciences and technology in the university programs."

Summary

- Fusion has great potential as a future energy option
- Program has made enormous technical progress and leveraged domestic resources with international collaboration
- Budget cuts have been large and costly in people and facilities
- Program has been restructured along lines drawn by Congress
- Program now needs funding stability in order to conduct a cost-effective scientific program
- ITER is a critical scientific and technological element of the program

Better Fusion

Through Science